Predictive Modeling Tools for Metal-Based Additive Manufacturing

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Description:

NIST seeks the development of tools that rely on a suite of physics-based and empirical models to support predictive analyses of metal-based additive manufacturing (AM) processes and products. Physics-based models will be developed in such a way to ensure reusability in a predictive environment, irrespective of product geometry. The tool will support reliable and repeatable microstructure and performance predictions for various geometries for a given process and material. Such a tool should:

- Provide a set of physics-based and empirical models for metal powder-bed fusion manufacturing processes.
- Demonstrate scaling and composability of such models to support geometry-independent reusability.
- Provide ranges of parameter values for which models can be assumed reliable and accurate.
- Provide support for in situ feedback to allow for real-time adjustments during manufacture.

The successful development of such a tool will provide industry with a mechanism to move away from empirical testing and instead rely more on modeling and simulation, enabled primarily by measurement science underpinnings. As a potential means for qualifying AM parts, the tool will support NIST's mission by reducing AM part lead-times and enabling SME's to expand their market participation.

Industry relies heavily on the manufacturing of coupons to qualify metal parts created using AM processes. Predictive models provide a means for industry to move away from their dependence on testing and towards an environment supported by models and simulation. The transition to modeling and simulation for part qualification is underway, albeit very cautiously and deliberately. Current qualification through modeling and simulation is achieved only with very specific models deployed under very specific circumstances.

The goal of this project is to develop a tool that will support the broader application of physics-based and empirical models as a means for product qualification. This will be achieved by developing sets of composable models, each model accompanied with clear application boundaries. These models must be composable to a level of granularity that microstructure, and to an extent performance, can be predicted to a degree of certainty, for a given set of process parameters and irrespective of geometry. This tool will be an early step in allowing industry to move away from 100% testing and towards reliable modeling and simulation in AM.

As AM nears production-ready capabilities, advancements in modeling and simulation have become increasingly necessary. Many institutions, especially universities and small companies, do not have the resources to test each part created. Nor do these institutions have the resources for developing reliable predictive models. Development for this tool will focus on support for composable modeling for metal powder bed fusion processes, including direct metal laser sintering and selective laser melting, though the principles applied during its development should support broader applications. Therefore, one goal of this project will be to provide a foundation for developing similar tools in the future for other processes, including those that build parts using polymer-based processes.

Phase I activities and expected results:

- Development of a set of parameterized, composable models to support predictive analysis in a proof-of-concept operating environment.
- Development of a specified set of operating conditions for which the models are applicable, including the degree of certainty that they are able to predict performance.
- Demonstration of model composability and reliability by predicting the microstructure, to a specified degree of certainty, for several basic shapes.
- Prediction of fabricated part performance of several basic shapes, to a specified degree of certainty.

Phase II activities and expected results:

- Demonstration of automated or semi-automated model composition to predict microstructure to a specified degree of certainty.
- Demonstration of identification of in situ adjustments based on real-time predictive analysis.
- Development of a tool from which models can be rapidly called and stored on demand.
- Demonstration of model composability and reliability by predicting the microstructure, to a specified degree of certainty, on complex geometry.
- Prediction of fabricated part performance of complex geometry, to a specified degree of certainty.

NIST staff from the Measurement Science for Additive Manufacturing Program in the Engineering Laboratory will work with the awardee, providing consultation and assessment of performance and progress, to develop the fundamental measurement science for this predictive tool. This will support development of a tool necessary to support composable predictive modeling for manufacturing with metal powder bed fusion processes, similar to how finite element analysis is used in conventional machining.

References:

1. Pollock, Neil, and Robin Williams. *Software and Organisations: The Biography of the Enterprise-Wide System or How SAP Conquered the World*. Taylor & Francis US. (2008).

2. Bourell, D., Leu, M., Rosen, D., eds. *Roadmap for Additive Manufacturing: Identifying the Future of Freeform Processing*, (http://wohlersassociates.com/roadmap2009.pdf). (2009).

3. Energetics Incorporated, *Measure Science Roadmap for Metal-based Additive Manufacturing*, (http://events.energetics.com/NIST-AdditiveMfgWorkshop/pdfs/NISTAdd_Mfg_Report_FINAL.pdf). (May 2013).